Our Radioactive World Notes

We live in a radioactive world. This presentation addresses the various ways in which we encounter ionizing radiation in our lives.

Slide 2 – natural radiation is everywhere

- we live in a radioactive universe
- we live on a radioactive planet
- we, like other lifeforms on Earth, are radioactive

Slide 3 – background radiation pie chart

- graphic shows various contributors to natural background radiation dose in pie chart format
- radon from radioactive decay of U and Th, both plentiful in Earth's crust
- terrestrial – mostly from uranium, thorium, and decay chain progeny
- cosmic rays – high energy, heavy, charged particles from sources in space
- cosmogenic radiation
  - results from cosmic ray interactions with atoms in Earth's atmosphere
  - except for carbon-14 (C-14), and sodium-22 (Na-22), which have metabolic roles in human body, cosmogenic radionuclides contribute little to radiation doses
- natural radionuclides in body primarily C-14 and K-40
- consumer products – anything made with Earthly materials likely radioactive

Slide 6 – cosmic particle shower

- high-energy particles incident on atmosphere interact with atoms and molecules to generate complex set of secondary charged and uncharged particles, including neutrons and pions, which decay into muons, electrons, and neutrinos
- charged pions (π^- and π^+) most often decay into muons and muon neutrinos; neutral pions (π^0) generally decay into two photons (gamma-rays)
- photons may further undergo internal conversions resulting in electron-positron pair as shown in graphic

Slide 7 – components of dose equivalent rate from cosmic rays in atmosphere

- graphic illustrates contributors to cosmic radiation exposure, which constitutes less than 10% of natural background radiation exposure
- charged-particle radiation primarily from muons, electrons, and protons

- long mean free path of muons in atmosphere makes them dominant component of charged-particle radiation at ground level, as shown in graphic
- muons contribute >70% of cosmic radiation exposure at sea level, electrons about 15%, neutrons <10%, and protons <5%
- at elevation of Denver and Albuquerque, exposure is about 50% from muons, about 20% from neutrons, <20% from electrons, and about 10% from protons
- at aircraft altitudes, neutrons, protons, electrons and photons most significant components of cosmic radiation
- Note that incoming protons, which initiate cosmic-ray neutron field, strongly affected by earth's magnetic field, with effect that neutron fluence rate in equatorial regions less than that in polar regions

Slide 9 – terrestrial radiation

- mostly from K, U, and Th
- graphic shows variations over U.S.
- average dose to individual in U.S. from terrestrial radiation sources ≈0.3 millisievert (30 millirem) per year, less than 10% of natural background radiation exposure
- residents in Colorado Plateau receive ≈4 times as much exposure as people living in Atlantic and Gulf coastal plain, but have 15% fewer cancers than national average

Slide 10 – common terrestrial radiation sources table

- long half-lives – most have been around forever
- U-238 and Th-232 have relatively long radioactive decay chains, producing numerous radioisotopes that contribute to terrestrial radiation dose
- although Ra-226 has relatively short half-life, continually produced from U-238 decay

Slide 11 – U-238 decay chain graphic

- natural uranium abundant in Earth's crust and consists of two very long-lived radioactive isotopes – U-235 and U-238
- both isotopes decay to stable isotope of lead as shown for U-238 in graphic
- all decay chain radioisotopes contribute to natural background radiation
- uranium decay chain radioisotopes in undisturbed uranium deposit in secular equilibrium with parent uranium radioisotope
- depending on mobility of U-238 and decay chain products in any uranium deposit, total activity of deposit could be up to 14 times U-238 activity

Slide 12 – thorium-232 decay chain graphic

- thorium-232 abundant in Earth's crust due to extremely long half-life of 14 billion years
- decays to stable isotope of lead as shown in graphic
- all decay chain radioisotopes contribute to natural background radiation
- as with uranium decay chain radioisotopes, Th-232 decay chain radioisotopes in undisturbed thorium deposit in secular equilibrium with parent Th-232 radioisotope
- depending on mobility of thorium and decay chain products in any thorium deposit, total activity of deposit could be up to 10 times Th-232 activity

Slide 14 – radioactivity in the body table

- all carbon-based life forms contain C-14
- K-40 has extremely long half-life (1.3 billion years) and is everywhere in our environment, including in food we eat
- human body contains trace amounts of uranium and thorium as well as other radioactive heavy metals like polonium and radium

Slide 15 – radioactive elements in human body

- table, based on calculations by R.E. Rowland, shows radioisotopes that produce most of radioactive decays that take place within adult body
- many other radioisotopes in body in addition to those listed, but most contribute very few decays per second, and thus trivial in comparison
- differences in activities from previous slide due to different data sets; previous slide data from ICRP 30 (1979), this slide data from NCRP Report No. 94 (1987)
  - ICRP is International Commission on Radiological Protection, NCRP is National Council on Radiation Protection and Measurements

Slide 16 – distribution of selected radionuclides in body

- graphic illustrates how chemical elements, both stable and radioactive isotopes, distributed in different parts of body
- soluble chemical elements enter bloodstream via absorption through GI tract (with differing absorption percentages), and distributed throughout body
- factors such as age and diet contribute to variability of element concentration
- element amounts that remain in blood (not deposited in tissues and organs) are excreted
- much of what is distributed throughout body by blood (including to kidneys, muscle, and other soft tissues) also excreted quickly

Slide 19 – radon decay chains graphic

- Ra-226 daughter radioisotope in U-238 decay chain

- Ra-224 daughter radioisotope in Th-232 decay chain

Slide 26 – radiation in the home
- radiation from consumer products one of smallest contributors to natural background radiation exposure
- radioactive consumer products found in American homes include smoke detectors, kitty litter, granite countertops, luminescent clocks, and compact fluorescent light bulbs
- radioactivity of consumer products below regulatory concern and present no health risk to people

Slide 27 – natural radioactivity in consumer products
- table shows natural radionuclides found in some common consumer products
- potassium-40 ubiquitous in Earth's environment and found in almost every kind of consumer product made from natural Earth materials

Slide 28 – radioactive building materials
- slide illustrates kinds of radioactive construction materials used in commercial and residential buildings
- small amounts of naturally radioactive elements like uranium, thorium, potassium and radioactive decay products found in common building materials

Slide 29 – radioactive building materials table
- units in picocuries per gram (10^{-12} Ci/g)
- K-40 everywhere in our environment, so can expect to find it in anything made of Earthly materials

Slide 30 – natural radioactivity in food
- much of what we eat is radioactive
- table shows radionuclides found in various food groups
- anything grown in soil contains K-40

Slide 31 – radioactivity in food table
- K-40, beta/gamma emitter, in many foods
- some foods have affinity for Ra-226 (alpha emitter); also soluble in groundwater